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## EXPERIENCES WITH TECHNOLOGY TRANSFER TO A RAPID TRANSIT SYSTEM

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### ABSTRACT

The NASA, in cooperation with the Urban Mass Transportation Administration, decided to experiment with a new technique for transfer of aerospace technology to the design of an urban rail rapid transit system. This involved a full-time on-site NASA Representative who was involved in the daily technical activities of the development of the Metrorail system for Metropolitan Dade County (Miami area), Florida. This report covers some of the impressions and opinions of the NASA Representative compiled after completion of the experiment, which took place from October 1977 to January 1980.

### INTRODUCTION

The National Aeronautics and Space Act of 1958 established as a prime NASA goal the "widest practical and appropriate dissemination of information concerning its activities and the results thereof." This resulted in the formation of the Technology Transfer Division, as a part of its Headquarters in Washington, D.C., to ensure that NASA meets this goal. In the performance of this mission, the Division has organized its activities on a nationwide basis to promote the effective secondary use of the vast amounts of new technology generated in the U.S. space program. This paper only covers one aspect of that technology transfer effort. It is considered an important aspect because it involved an experiment in a new technique for such a transfer to a specific industry.

#### Background

The energy crises has created an increasing need for providing for transportation of people through high

density populated urban areas by more efficient methods than the automobile. The Urban Mass Transportation Administration (UMTA) under the Department of Transportation has therefore been engaged in activities for development of new rail rapid transit systems, upgrading old systems, and expansion of existing properties. Emphasis has been placed on rail with fixed guideways above and/or below existing street traffic because it can transport far more people in both density and time than any other known means of transportation. The need for increased capacity urban public transportation has been accompanied by a need for effective use of advancing technology to improve the capability and efficiency of rapid transit systems.

#### Technology Transfer

Many people who have not been involved in technology transfer feel it is a simple process. Experience in this activity soon convinces participants that it is far more complicated than many government and industrial managers realize. For example: this addition of new technology to an already complex transit system, in at least one case, led to more frequent failures, increased maintenance requirements, and less system availability.

NASA and UMTA subsequently made an agreement to try a different approach to such transfer to a new urban mass transit system. This called for a full-time on-site NASA selected representative to the Metrorail transit system development in Metropolitan Dade County (MDC), Florida. This new approach was initiated in October 1977 for a "six to eight month trial effort". The experiment was completed in January 1980.

This paper briefly covers the impressions of the assigned NASA Representative regarding that technology transfer activity and may or may not reflect the opinions of the UMTA, NASA, or Metropolitan Dade County management. The preliminary impressions of the MDC management and the NASA Representative were presented to the Space Congress in 1978.

#### WHY

A question in many minds is what does NASA have to offer an urban mass transit program? The answer is that there are some surprising similarities between the Space Shuttle ground operations to be conducted at the Kennedy Space Center (KSC) and the three rail, fixed guideway train system being built in Metropolitan Dade County. For example, both have to:

- Operate in a semi-tropical marine climate that presents both lightning and severe corrosion problems.
- Place emphasis on the safety of the crew, passengers, and the uninvolved public.
- Provide repetitive predictable service.
- Operate within strict budgets.

#### TECHNOLOGY TRANSFER PROBLEMS

The basic approach to technology transfer has been to make available large quantities of technical information. Assistance is provided to help the requestor to locate specific material which is then made available for use as they see fit. Sometimes this works and sometimes it turns into an unpleasant experience because the application was not quite right.

The major problem areas in such transfers are:

**Semantics** - A principal barrier to the transfer of aerospace technology to the transit industry is semantics. The same word or acronym is often used in a different context and/or with a different meaning in a rapid transit technology than it is in aerospace technology. As one example, NASA defines Risk Management as a program management and control methodology for identifying, analyzing, and controlling risk situations on the basis of the application of design engineering

principles that include system safety, reliability, availability, and maintainability. In comparison, the American Public Transit Association has no entry for Risk Management; the term closes in meaning, yet not the same, is Systems Assurance. Consequently, NASA documentation that is provided is subject to misinterpretation.

**Specifications** - The NASA and military (MIL) specifications, such as those for reliability and quality assurance (R&QA), are intended for complete use only in the most extreme cases. This degree of R&QA in aerospace is established separately for each project, and only those segments of the specifications that are deemed to be pertinent are selected for further use. Many are unaware of this point. Therefore it is the potential misuse or lack of understanding of NASA and MIL specifications, that makes the NASA management systems appear to be too complicated and too costly for use in the transit industry.

**R,D,T & E** - The production of a new system in the Space Program usually is justified on the rationale that it will provide a significant advance in performance capability. Before production commences, however, extensive RDT&E activity occurs to solve problems that can be expected to arise in all new designs. This includes the necessary design and qualification of new components and systems. The development of a new rapid transit system (e.g., Metrorail), however, is quite different in that rapid transit systems must feature already proven equipment and facilities. RDT&E funding is generally not included in transit capital improvement projects. Therefore, because first-time use of a new technology usually is too much of a risk for the rapid transit industry, technology transfer is constrained.

**Human Factor** - Most organizations include people who are suspicious of new concepts or technology and who resist change. This situation in any industry results in attempts to nullify any technology transfer effort, often with the excuse that "the technology is too expensive" or that "it is too sophisticated". In addition, subordinates in a user organization sometimes resist technology transfer because they believe that it reflects poorly on their capabilities or that it may threaten their positions.

Strong management support is needed to overcome this human factor barrier. Just as top management support of technology transfer at a NASA center plays an important role in determining the quality and quantity of technology supplied, top management support in the user organization plays an important role in determining the extent to which the technology is properly implemented. In some cases, top management must order acceptance and proper usage of the technology before any benefit can be realized.

#### FULL-TIME, ON-SITE APPROACH

The basic premises of this technology transfer methodology are that a full-time technology transfer agent working on-site can overcome the barriers inherent in technology transfer to provide a usable flow of hardware and management systems information to the user. Two factors related to this method are significant:

•Such representation cannot constitute consultant services because NASA is not authorized to provide such service. Information about technology is provided in response to identified needs that can draw on NASA experiences, methods, and hardware technology. Illustrations regarding how the information can be used, based on aerospace experience, are acceptable. The final decision as to what and how to use the information is the prerogative and responsibility of the user.

•The usefulness of the technology transfer is based on the quality of the information provided and how it is utilized.

This innovative method has several advantages over other methods of technology transfer now in use. The Representative's previous NASA experience proved to be essential to the technology transfer to the MDC project. The Representative was able to locate through personal contacts with NASA specialists the most applicable technology for use in MDC project. This direct access to applicable technology also helped the NASA Representative meet the MDC's desired response times. Moreover, the Representative's firsthand understanding of the user's needs and limitations coupled with his NASA experience resulted in more efficient and cost-effective presentation of the technology.

Both "pull" and "push" methods of technology transfer were used in the pilot project. The "pull" method was initiated by the users who were seeking specific information. This required that they identify what they considered to be major technological problem areas in the Metrorail project. In response, the NASA Representative not only searched for the applicable information and made it available, but also provided suggestions for its most effective application.

In the "push" method of technology transfer, the NASA Representative initiated the action. By relating on-site participation in the project with past NASA experience, it was possible to recognize areas where certain NASA technology could be applied where the user may be unaware of its existence. As in the "pull" method, the NASA Representative made the technical information available and suggested how it could be used.

The methodology used by the NASA Representative to transfer NASA technology had the following tasks:

- (1) Identify a problem as transmitted from user personnel and/or as observed.
- (2) Search for information through the technology utilization, science, and engineering offices of the NASA.
- (3) Supply applicable technological information along with suggestions of how to apply and use it.
- (4) Show that the information provided can be used within the state-of-the-art of transit industry technology.
- (5) Be available for questions, comments, and requests for additional information.

The same procedure was used to provide inputs involving various management systems such as risk management, and configuration management control.

#### TRAINING THE NASA REPRESENTATIVE

The full-time on-site representation concept proved vital to the NASA Representative. The scope of a transfer agents' technical capabilities and experience proved not to be too use-

in the final version of the specifications.

\*In the search for relevant corrosion control documentation for TSD, the NASA Representative could not find a single, comprehensive, practical corrosion control handbook for design, fabrication, and maintenance engineers. Consequently, a suggested handbook outline and development plan were prepared to request funds from NASA for development of a corrosion handbook based on NASA and DOD corrosion control technology that would be applicable for the rapid transit industry. The MDC management also asked the UMTA Associate Administrator for Technology Development and Deployment to support the project because it would be useful to all transit properties. As a result, UMTA and NASA have agreed to co-fund the development of a "Corrosion Control Manual for Rapid Transit Systems" and corrosion control specialists of the U.S. Armament Material Readiness Command and Kennedy Space Center have agreed to develop the handbook. This one year project began in December 1979.

#### EMI

An electronics manufacturer whose plant is adjacent to the MDC rapid transit right-of-way has formally stated a concern that: (1) the chopper (frequency modulation) transit car motor controllers will produce an electromagnetic interference (EMI) that will affect the plant's operations and products, (2) the third rail will present similar problems, and (3) the AC-DC rectifiers will induce interference in the industrial power supply. Because MDC had to thoroughly investigate the complain to maintain good public relations and they lacked EMI expertise, a request was made to the NASA Representative for technical assistance.

Accordingly, the NASA Representative took the problem to EMI specialists at KSC and MSFC to draw on NASA's considerable experience with EMI as both the originator and the affected party. It was suggested that MDC first have tests conducted to establish both the current ambient EMI conditions at the manufacturing plant and the nature and intensity of emission from similar rapid transit vehicles. If the problem is real,

technical solutions on how to rectify the situation are available.

#### Fire Safety

Fire is a problem in any passenger-carrying vehicle. Although major fires are not common, they have occurred in rapid transit vehicles. NASA has not been immune to the problem of fires and has been developing and testing nonmetallic materials for greater fire safety in aircraft and spacecraft. The object is to find materials that exhibit the least degree of reaction regarding ease of ignition, flame propagation, smoke amount and density, and emission of toxic vapors.

Information has been transferred pertaining to the elimination of fire through the selection of materials that will not sustain fires. The most extensive information has come from the "Johnson Space Center Nonmetallic Materials Design Guidelines and Test Data Handbook" that presents the test results of thousands of materials. The Metrorail staff and contractors apparently used some of the material as evidenced by changes in the vehicle procurement specifications, such as:

- \*Materials callouts were changed to performance requirements to better ensure use of the latest state-of-the-art developments.
- \*Requirements for burn and smoke tests were included.
- \*The specifications on aluminum fasteners were revised to reduce the possibility of failure during a fire.
- \*More concern for the selection of fire resistant and low-smoke materials.

#### Solar Energy

NASA was one of the original users of solar energy and has been a leader in solar energy technology in cooperation with the Department of Energy. A representative of NASA's Lewis Research Center gave an excellent presentation for MDC in Miami on the use of solar cells and a Marshall Space Flight Center representative later gave MDC a similar presentation on solar collectors. Useful documents were also given to the County representatives.

ful to the potential user until after a training period. The participation in the daily technical activities enabled learning to converse in the users' language. This is important in covering a broad range of technical problems both with respect to recognition and identifying any potential solutions.

However, the most difficult problem for one with an aerospace background is understanding the restraints due to funding. The funds provided for rapid transit properties include little or no monies for development, test, and qualification of an item. This means that a large quantity of the aerospace expertise is of no value to this industry because they lack a means to properly qualify such equipment for their use. Unless such equipment has been subjected to appropriate tests and qualifications it is too great a risk to attempt to utilize it. Improper qualification was, in the opinion of the author, the major reason of the previous stated example where new technology degraded instead of improving a newly designed transit system.

#### EXAMPLES OF THE TRANSFER

The problems of technology transfer have been given emphasis. On the more positive side it is felt useful to show specific examples of technological and management systems that were made available to the Metropolitan Dade County, Florida, transit system development.

These include, but were not limited to the following:

**Lightning Protection.** Florida has the highest frequency of lightning strikes in the United States. This forced KSC to develop methods of protection, especially on the launch pads.

A complete package of NASA and DOD technical documentation was provided to allow:

- \*Determination of the severity of the problem.

- \*Designing a lightning protection system for any structure based on empirical data.

- \*Prepare specifications to cover lightning protection including bonding and grounding requirements proven by use at KSC

#### Corrosion Control.

A characteristic of the Florida central and southeast coast is a semi-tropical marine climate with the prevailing winds coming inland from the ocean. This condition causes corrosion problems more severe than any found elsewhere in the continental United States. Consequently, corrosion control is a major concern.

Because of the complexity of the subject and its importance, the NASA Representative transferred more documentation on corrosion control than any other subject. Information was also provided on specific design problems including but not limited to:

- \*KSC's favorable experience with protecting carbon steel and aluminum with zinc-rich coatings was related. In addition, a list of NASA-qualified sources for the coatings and application and maintenance specifications were supplied.

- \*DC power systems, such as those used in rapid transit, introduce currents into the ground. These stray currents cause underground cathodic corrosion of metallic objects, such as pipes and foundation reinforcing steel. KSC solved the same problem with the Vertical Assembly Building by inducing a current of equal strength and opposite polarity in the ground around the building. This has worked successfully at KSC for more than ten years. This and other known cathodic protection methods were described to MDC. The results of an analysis determined, however, that none are cost-effective for long-term rapid transit use because cathodic protection has to be incorporated along the entire track network.

- \*Since "virtually all corrosion failures result from improper application, carelessness on the part of the user, or poor choice of materials", (Ref.) materials selection, design fabrication, and maintenance techniques are the key to corrosion control.

MDC also asked the NASA Representative to review the transit car procurement specifications to determine if NASA's experience with corrosion control could improve them. Approximately 20 technical suggestions were made, and most were incorporated



A pilot solar energy utilization project has been planned as part of Stage I of the Metrorail system. If effective, it might be used more extensively in later expansions of the transit system. Although MDC received information sufficient to design solar heating, solar cooling, and emergency lighting systems, no action has been taken to date due to lack of funding.

#### Floodlights

MDC management asked what type of outdoor floodlights are used at KSC and why. KSC uses high-pressure sodium vapor lights because they require less power to operate than other lights with equivalent illumination and are cheaper to install and maintain.

On the basis of this cost-saving rationale, the MDC rapid transit system will also use high-pressure sodium vapor lights in stations and parking lots. MDC also plans to change all its roadway and high crime area lights to high-pressure sodium vapor.

#### Fireboat

The city of Miami has about 27 miles of waterfront, most of which is in commercial and private boating use. However, the city lacks any fireboats to fight fires from the waterside, whether the fire is in another boat or a building. The lack of fireboats is mainly attributable to the high cost of buying, maintaining, and operating such vessels. There is also a concern that a Metrorail train may catch fire on the high, wide bridge that will span the Miami River (with clearance for ocean-going ships).

Marshall Space Flight Center (MSFC) has developed a high-capacity, completely self-contained, portable water pump for fighting fires on or near a body of water. The U.S. Army has a surplus of LARK V amphibious troop carriers, and the idea of maintaining the MSFC pump on a LARK was conceived to obtain an inexpensive fireboat.

As a result, a prototype installation and test was conducted by the Miami Fire Department. Several suggestions by the NASA Representative to improve the maintainability and reduce the noise level of the pump, as well as a rough-water test program for the LARK, were implemented.

#### Specifications

To benefit from direct NASA experience technology transfer, the NASA Representative was requested to review and suggest improvements to the system and vehicle specifications several times during their development. These reviews concentrated on determining that:

- Callouts/requirements reflected the state-of-the-art.
- The scope of the documents was adequate to meet management objectives.
- Adequate coverage was given to corrosion and fire prevention.

#### MANAGEMENT SYSTEMS

The complexity of the Space Program forced the development of new management systems as well as improvement of old systems. Generally, the more complex the problem, the greater the demand for attention to details. NASA learned that attention to details should never be left to chance. In aerospace projects, good management requires proper definition of requirements and objectives, controls, and processes that reduce guesswork to the lowest possible practicable denominator. Emphasis is placed on documenting decisions and the rationale on which they were based. This information is vital when expenditures and prior actions are under the inevitable critical reviews that occur later.

As rapid transit systems become more and more complex, many of the management systems that NASA has successfully used are now being adapted and used in the transit industry. The following NASA management systems were made available:

- All management functions involve risk. Some managers wait until something happens and then react to a crisis; others plan for a crisis, but sometimes find that they failed to consider all the potential problems. The NASA Risk Management system is a methodology for identifying, analyzing, and controlling risk situations.

For purposes of illustration, the MDC requested an overview of the way in which the NASA Risk Management concept would be applied to local fire and lightning hazards. The Representative prepared a paper, "Method

for Fire and Lightning Protection in the Rapid Transit System Based on the NASA Risk Management Concept" and submitted it in January 1979. The application of NASA Risk Management methods to local fire and lightning hazards was fully developed in rapid transit terminology and requirements.

After review of the paper, Metropolitan Dade County management asked how the method could be integrated with the Metrorail project. Specific suggestions on the way in which Risk Management could be used without becoming a major cost factor were supplied in a second paper entitled, "Method for Adoption of a Risk Management Process for the Rapid Transit System of Metropolitan Dade County, Florida" in January 1979. On the basis of the information presented in the two papers, the MDC management integrated the Risk Management method into the system safety planning and the safety certification functions that are required before the initiation of revenue operations.

Many projects have progressed from the design and construction phases into operations with inadequate reference documentation and configuration control for user and maintenance needs. This deficiency always increases costs. Every contractor, manufacturer, and vendor uses internally generated technical documentation that is identified by his own designation. In various aerospace and rapid transit projects, the number of primary and secondary contractors (e.g., architectural and engineering firms, special consultants, manufacturers, vendors, and installation groups), can easily vary from a hundred to several thousand. Each contributes something to the project.

The configuration of an equipment item or facility is the description of the functional and/or physical characteristics of that product. Configuration management is the discipline that ensures that equipment and facility configurations are documented to the extent needed for the user to assess proposed changes, develop maintenance plans, perform maintenance, procure spare parts, describe operations procedures, and specify new procurements. In addition, it ensures that changes are systematically identified, evaluated,

coordinated, approved or disapproved, and implemented.

In the design and construction of buildings and structures, a special problem that often occurs is that the architect's specifications can sometimes require construction procedures that fall outside the scope of the contractor's experience and industry practice. Such problems between the designer and the contractor often result in delays in construction and/or changes in the design. Either situation creates an undesirable rise in the cost of construction.

Constructability is a "coined term" that refers to the simplest procedure for facility design and planning orientation that the general contractor can follow using standard industry techniques. Another aspect of constructability is phasing the installation times of two or more contractors to ensure that their combined product is assembled in the most efficient way. This part of constructability is better known as systems integration and interface control in the aerospace industry.

## RESULTS

The degree of success of a technology transfer effort is hard to evaluate. Placing a dollar value on it is usually impossible because the benefits are intrinsic and often in the case of rapid transit, folded into the design in a way that causes a loss of individual contribution identity.

In this experiment the NASA Representative felt a steady increase in productivity because of improving responses to the information presented. Also, the requests for inputs from the engineers went from zero to a significant level.

Management reactions were to extend the experiment from the original 6 to 8 months to over two years.

When the transfer experiment was initiated in October 1977 the MDC management provided a list of eight items in which technical inputs were desired. The experiment ended with the NASA Representative holding a self generated list of thirteen areas where more NASA inputs were needed. This seems to be a mark of progress.



## RECOMMENDATIONS AND IMPRESSIONS

On the basis of this experiment the former NASA Representative has recommended and concluded that:

- The full-time on-site representative concept would be useful if utilized in critical industries where better technology is sorely needed.
- Since the financial losses to industry and the government (and the individual taxpayers) due to corrosion has gone into the multi-billion dollar range, all funds devoted by NASA and UMTA to control this phenomena would be very valuable to all industries. To date, it has been a sorely neglected subject and should be given emphasis by the government.
- NASA has made tremendous strides in computer control and automation as demonstrated in such projects as Apollo, landing on Mars, and the Jupiter and Saturn fly-bys. This technology has not been adequately transmitted to the rapid transit industry which has an increasing need for better automation.
- The technology transferred to MDC can be used by all transit properties.
- Personal contact with NASA and MDC technical personnel was more effective than any other available procedure for technology transfer.
- The on-site approach resulted in better understanding of MDC technology needs than the other methods of technology transfer now in use. Technology transfer effectiveness is enhanced in direct proportion to the degree of understanding of the user's needs.
- Personal contact with NASA scientists and engineers is a substantially more effective and efficient method to obtain needed technological information than the (computerized) literature search methods.
- The best technology transfer results are obtained when the users are shown how the technology can be adapted to their need.
- Technology transfer cannot be realized without management support in both the provider and potential user organizations. User management needs

to encourage, and in some cases demand, that their personnel accept and use new technology.

## ABBREVIATIONS

MDC	Metropolitan Dade County, Florida
APTA	American Public Transit Assoc.
UMTA	Urban Mass Transportation Administration
RDT&E	Research, Development, Test and Evaluation
KSC	Kennedy Space Center, Florida
MSFC	Marshall Space Flight Center, Alabama

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